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(54) Micromechanical barb and method for making the same

Mikromechanischer Widerhaken und Verfahren zu seiner Herstellung

Barbelure micromécanique et son procédé de fabrication

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EP 0 497 620 B1

Description

The present invention pertains to fastening systems. More specifically, the present invention pertains to a micromechanical fastener as well as a system and method for its use.

There is essentially an infinite need for linking two distinct members or objects to each other. Some common techniques for linking two distinct objects are adhesively bonding them together with, for instance, glue, soldering them together or fastening them together with, for instance, a nail or nut and bolt arrangement to name but a few of the techniques. However, as the size of the objects to be linked becomes smaller and approaches the microscope level, many of the techniques for linking larger objects are no longer available.

With the advent of technologies that allow for the relatively easy production of microminiature devices and components, the ability to link such devices or components becomes an increasingly important problem. While adhesives are available for use, due to their chemical nature, not all environments are conducive to their use to link microminiature components or objects. What is needed is a more versatile technique to link microminiature objects.

US 3266113 discloses a fastener of conventional, i.e. large, scale which takes the form of pairs of articles each having a functional surface on which multiple, two-dimensional rows of elastic locking elements are arranged on a rigid backing member. These elastic locking elements are not rigid and are able to flex to one side. When the pairs of articles are placed together the elastic locking elements deflect, generally into positions left vacant, to allow engagement of the heads of the elements to fasten the pairs of elements together. The arrangement disclosed allows for easy detachment of interlocking parts.

In IBM Technical Disclosure Vol. 31, No. 12 pages 414 and 415 there is disclosed a method of producing "fir-tree Masks" using etching processes and EP-A-095172 discloses a chemical etching method which is applicable, for example, to the manufacture of printed circuits.

US 4259959 discloses a fastener also of relatively large scale which is for use as a suturing agent and comprises a backbone or strip of flexible material with numerous hooks extending therefrom in at least two directions. It is used by inserting it into the wound so that the hooks snag the tissue edges and hold them together while the wound heals.

US 4793348 discloses a filter for use in the blood vessel the vena cava to prevent the migration of blood clots into the pulmonary circulation. The filter is provided with a plurality of hook-like tines around its extremities by which it may be secured within the blood vessel by the tines embedding themselves within the vessel wall.

GB-A-2221394 discloses a drug delivery device in which the drug is delivered to the subcutaneous layer of a patient's skin via a number of hollow filaments which pierce the skin and are in contact with a flexible sachet containing the drug in liquid form.

DE-1784067 discloses a fastener for use in the manufacture of walls and ceilings, in particular for the holding of cladding materials. The fastener is of conventional large scale and allows removal of cladding plates without damage. It involves strips of connecting material which on one side have a plurality of closely spaced projections for which numerous shapes are taught. The projections are elastic and flexible and upon interlocking spring back together to form a temporary connection.

DE-A-1807993 discloses a conventionally scaled two-piece connector of a tough elastic material which is formed from two identical parts each having retaining pegs being enlarged at the free ends which can be positively locked together. They connect by elastic deformation of the retaining pegs and are releasable.

GB-A-2124293 discloses a conventionally scaled fastener for fixing a framework or lattice work, e.g. a wire mesh. It is specifically to be used in the construction industry for rendering buildings needing repair. An arrow-like projection is disclosed which resiliently deforms and springs-back to lock the mesh in place.

According to the present invention there is provided a micromechanical fastener capable of linking to an object, comprising:

a base;
a support which extends from, and is in substantially rigid connection with, the base; and
a head which is disposed upon the support and has a central or connection portion which is in substantially rigid connection with the support, and has an extremity or attachment portion which extends laterally from the central or connection portion and which creates an anchoring connection with the object,
wherein the combined height of the support and the head above the base is less than 0.5 millimetres;
wherein the head, base and support are made of a substantially rigid material; and
wherein the head, base and support form a monolithic structure.

The central portion may be provided with a top surface having a pointed shape that is capable of facilitating penetration of a surface of the object by piercing.

The object may be another micromechanical fastener according to the present invention and the extremity portion may be adapted to deflect and subsequently spring back when contacted with extremity portions of the other micromechanical fastener to form a locking connection therebetween.

According to the present invention there is further provided a micromechanical fastening system for linking a first member with a second member comprising:

a first plurality of micromechanical fasteners according to the present invention disposed on the first member;
a second plurality of micromechanical fasteners according to the present invention disposed on the second member;
wherein the first and second plurality of fasteners oppose each other.

According to the present invention there is yet further provided a method for making a plurality of micromechanical fasteners or a fastening system according to the present invention, which method comprises the steps of:

forming a substrate of a first material from which the base of the fastener is formed;
forming a first layer on the substrate of a second material from which the support is to be formed; and
forming a second layer of a third material at predetermined discrete locations on the layer of second material;
removing portions of the first layer and the substrate but not the second layer such that a frustumshape is formed on the surface of the substrate;
removing the second layer but leaving the substrate and first layer essentially untouched;
forming a new layer made of the material from which the head is to be formed on the frustum surface such that the frustum shape is retained;
removing portions of the new layer at essentially the centre of the lowest points of the frustum; and
removing portions of the first layer and the substrate but not of the new layer such that the micromechanical fastener or plurality of micromechanical fasteners is created.

The present invention pertains in part to a system for linking a first member with a second member. The system is comprised of a first plurality of micromechanical barbs disposed on the first member. The system is also comprised of a second plurality of micromechanical barbs disposed on the second member. The barbs on the first member and the second member are of a shape such that a locking connection is formed between the first member and second member through the first plurality and second plurality of barbs when placed together. Each of the barbs of the first plurality and second plurality of barbs extend from the first member and second member, respectively, to a height no greater than 0.5 millimetres. The first plurality of barbs and second plurality of barbs oppose each other.

The present invention also pertains to a micromechanical barb for linking with an object. The micromechanical barb comprises a base. The micromechanical barb is additionally comprised of a support which extends from the base. The micromechanical barb additionally is comprised of a head which is disposed upon the support and which mates with the object such that a locking connection is found therebetween. The length of the support and the head is less than 0.5 millimetres.

The present invention also pertains to a method for making a plurality of barbs. The method is comprised of the steps of first forming a substrate of a first material with a layer of a second material thereon, and at predetermined discrete locations on the layer a third material. Next, there is the step of removing portions of the layer and the substrate such that a frustrum shape is formed on the surface of the substrate. Next, there is the step of removing the third material but leaving the first and second materials essentially untouched. Then, there is the step of reforming the layer made of the second material on the frustrum surface of the substrate. Next, there is the step of removing portions of the layer at essentially the centre of the lowest points of the frustrum. There is then the step of removing portions of the substrate but not the second material such that a plurality of barbs is created.

The present invention additionally pertains to a connector produced by surface micromachining. The connector comprises a first portion which lockingly connects with an object. The connector is also comprised of a base upon which the first portion is fixedly disposed.

In the accompanying drawings, the preferred embodiments of the invention and preferred methods of practicing the invention are illustrated in which:

Figure 1 is a schematic representation of a cross section of a first plurality of barbs and a second plurality of barbs adjacent to each other.

Figure 2 is a schematic representation of a first plurality of barbs 16.

Figure 3 is a schematic representation of a cross sectional view of a first plurality of barbs and second plurality of barbs in linking connection with each other.

Figure 4 is a schematic representation of an overhead view of a barb.

Figure 5 is an electron micrograph of an array of barbs.

Figure 6 is a side view of an alternative embodiment of a barb which pierces.

Figure 7 is an electron micrograph of a piercing barb.

Figure 8 is an electron micrograph of a plurality of piercing barbs in linking connection with the epithelial layer of a vena cava.

Figures 9a-d is a schematic representation of a process for producing barbs.

Figure 10 is an overhead view of a mask pattern for use in the process depicted in Figure 9.

Figures 11a-c are schematic representations of an apparatus for connecting tissue.

Figures 12a-c are schematic representations of an expandable cylinder for lining a blood vessel.

Figure 13 is a schematic representation of an apparatus for providing a drug into an organ.

Figure 14 is a schematic representation of electrical

components being electrically connected when together with electrically conductive barbs.

Figure 15 is a schematic representation of electrical components being mechanically connected together with barbs.

Referring now to the drawings, wherein like reference numerals refer to similar or identical parts throughout the several views, and more specifically to figure 1 thereof, there is shown a system 10 for linking a first member 12 with a second member 14. The system comprises a first plurality of micromechanical barbs 16a disposed on the first member 12. The system 10 is also comprised of a second plurality of micromechanical barbs 16b disposed on the second member 14. The barbs 16a on the first member 12 and the barbs 16b on the second member 14 are of a shape such that a locking connection is formed between the first member 12 and second member 14 through the first plurality of barbs 16a and second plurality of barbs 16b when they are placed together.

Each of the barbs 16a of the first plurality of barbs 16a and each barbs 16b of the second plurality of barbs 16b extend from the first member 12 and second member 14, respectively, to a height no greater than 0.5 millimetres. The first plurality of barbs 16a and second plurality of barbs 16b oppose each other. Preferably, the barbs 16a of the first plurality of barbs 16a and the barbs 16b of the second plurality of barbs 16b are of the same shape.

As shown in figure 2, each barb 16 is comprised of a support 18 which extends from its respective member. Each barb is also comprised of a head 20 which is disposed upon the support 18 and which mates with the heads 20 of barbs 16 on the opposing plurality of barbs 16 as shown in figure 3.

In general, a micromechanical barb 16 can be used for linking with an object that will mate with the barb 16. A support 18 can extend from any type of a base 22, whether that base 22 be a first member 12 having other barbs 16a, or a second member 14 having barbs 16b, or whatever type of rigid material that is conducive to the formation and support of the barb 16. The rigid material is such that the barb which is made of it can sustain a locking relationship with other barbs or pierce an object and maintain a locking relationship therewith, as described below. Thus, essentially, a micromechanical barb 16 is comprised of a base 22. It is also comprised of a support 18 which extends from the base 22. Additionally, the barb is comprised of a head 20 which is disposed upon the support 18 and which mates with the object such that a locking connection is formed therebetween. The length of the support 18 and the head 20 are less than 0.5 millimetres. Preferably, the base 22, head 20 and support 18 are integral with each other.

The head 20 preferably has a central portion 24 which is connected to the support 18 and an extremity portion 26 which extends from the central portion 24 and which directly forms the locking connection with the object. The base 22, head 20 and support 18 are made of a rigid material. The rigid material can be, for instance, metal, ceramic, plastic, composite material or alloy. The metal could be steel, the ceramic could be aluminium oxide, the composite material could be graphite fibre matrix composite and the plastic polysulfone. Preferably, the base and support are made out of Si and the head is made out of SiO_2.

The extremity portion 26 preferably forms an angle θ, which is less than 90°, with the central portion 24 such that the extremity portion 26 extends from the central portion toward the base 22. The extremity portion 26 is preferably in the shape of a cross 28, as shown in figure 4 formed of four legs 30 to facilitate mating with another barb's 16 extremity portion 26 of identical shape. An electron micrograph of an array of mating micromechanical barb 16 is shown in figure 5. The central portion 24 of the head 20 in this picture is 1.0 µm SiO_2 on silicon support 18. Of course, the extremity portion can be of any shape that facilitates the latching of the object upon contact therewith by the head 22.

In an alternative embodiment the central portion 24 has a top surface 32 with a pointed shape that facilitates penetration of the first member 12 by piercing as shown in figure 6. Figure 7 is an electron micrograph of a piercing micromechanical barb 16 that has a central portion 24 with a pointed shape that facilitates penetration of the first object.

The object can essentially be made of anything that is of a material that can be pierced by the central portion 24 with a pointed shape; or which can maintain a second array of barbs 16 that can mate with barbs extending from the base 22, and which is of a material that is also rigid enough to cause the extremity portion 26 to latch without separating if a predetermined level of force is not present. For example, the mating barbs 16 can be used as an electrical interconnect with respect to the input/output connections for an integrated circuit chip. The mating barbs 16 of the present invention provide a high quality electrical, thermal, and mechanical connection simultaneously, and can be fabricated directly on the chip with electronic circuitry. The inherently self-aligning aspect of the present invention (i.e., the mechanical compliance accommodates small misalignments) serve to facilitate the mounting of IC's on carriers, which is a major difficulty with present technology. As shown in figure 14, electrically conducting barbs 84 are electrically connected to an interconnecting carrier 86 and to a first IC 88 and a second IC 90. By connecting the first IC 88 and the second IC 90 to the interconnecting carrier 86 through the conducting barbs 84 electrical connector is formed therebetween. Alternatively, as shown in figure 15, a first semiconductor wafer 92 and a second semiconductor wafer 94 can be mechanically bonded together with barbs 16 while electrical bonding pads 94 on the wafers serve to electrically connect the wafers.

With respect to the piercing barb 16 that has a central portion 24 with a pointed shape it could be used to

bond with objects having unprepared surfaces. For example, a surface consisting of piercing barbs 16 would be able to pierce skin or other tissues for medical applications. There could be an annulus studded on both sides with the piercing micromechanical barbs 16. As shown in figure 11, there is an apparatus 50 for connecting tissue. The apparatus 50, preferably an annulus 52, is comprised of a first side 54 and an opposing second side 56, as shown in figure 11b. On each side, there is a plurality of micromechanical barbs 58. These barbs 58 essentially piece the tissue 60 and hold it together. As is better shown in figure 11c, the tissue 60 can be a blood vessel 63 of some form, such as a vein or artery that is connected with the annulus 52. The opening 62 of the annulus allows the blood to flow therethrough. Preferably, the annulus 52 is comprised of segments 64 formed, for instance, by scored grooves in each side of the annulus 52. These grooves allow the annulus to have flexibility so it can bend, without breaking. This is important in circumstances where a pulse of force passes through the blood vessel 63, such as that associated with a heart beat. When the blood vessel 63 is attached under pressure to the annulus 52, the annulus breaks apart along the grooves.

There could also be an expandable cylinder 66, the outside of which is blanketed with the piercing barbs 16, which undergo plastic deformation when expanded, a shown in figure 12. The expandable cylinder could be used as a stent for holding blood vessels open after angioplasty. For instance, plaque 65 in a blood vessel 63, as shown in figure 12a, can be removed by known techniques. Then, the expandable cylinder 66, with the barbs 16 about its outside surface, and which has a balloon 67 inside it, is inserted into the blood vessel 63. The balloon 67 is expanded, as shown in figure 12b, causing the cylinder 66 to expand and the barbs 16 on its outer surface to piece the blood vessel 63, resulting in the cylinder being held against the blood vessel 63 inner lining, as shown in figure 12c. The balloon 67 is then removed from the vessel 63 and the blood is allowed to flow unrestricted as before. However, with the cylinder 66 now in place, the vessel remains patent. The expandable cylinder 66 can be an elastomer not reactive with human fluids. Individual strips of the barbs 16 can be glued onto the surface of the cylinder 66.

Hollow piercing barbs 72 could be used to deliver drugs 74 through them directly to the point of attachment on an organ 76, as shown in figure 13. A reservoir 78 in the base 80 holds the drug 76. A microminiature pump (not shown) could also be used to control the flow of the drug 76 into the organ. The hollow channel 82 in the barb 72 can be formed, for example, with a laser or an isotropic etch which penetrates into the base 80 only in one direction which does not spread out as it etches. The reservoir can be formed by etching the base so an opening is formed therein. The drug is then placed into the opening to form the reservoir. The base is then sealed by placing a cap over the opening.

Additionally, sheets of piercing barbs 16 could be used as skin bandages to close incisions or wounds. Figure 8 is an electron micrograph of a plurality of piercing barbs in linking connection with the epithelial layer of a vena cava. Figure 8 reveals the barbs 16 penetrating the epithelial membrane of the vena cava.

Another use of the barbs 16 is in the interfacing of microdynamic machines to the macroscopic world. By their nature, submillimeter electromechanical devices, such as pressure, velocity and acceleration sensors, operate in a regime where mechanical contacts to the macroscopic "outside world" are problematical. The present invention provides an approach by which the vastly different scales of conventional and micromachining may be joined. The advantage of this method over fusion and electrostatic bonding include low temperature processing, absence of external chemical and electrical agents, and simplicity, e.g. wire bonding.

A method for making a plurality of barbs 16, and referring to figures 9a-d, comprises the steps of first forming a substrate 34, such as Si or steel, with a layer 36 of a second material, such as SiO_2, thereon, and at predetermined discrete locations 28 on the layer 36 a third material, such as a photoresist as shown in figure 9a. Then, there is the step of removing portions of the layer 36 and the substrate 34 but not the third material such that a frustrum shape is formed on the surface of the substrate 34, as shown in figure 9b. Next, there is the step of removing the third material but leaving the first and second materials essentially untouched as shown in figure 9b. Then, there is the step of reforming the layer 36 made of the second material on the frustrum surface of the substrate 34 such that it also forms a frustrum shape, as shown in figure 9c. Next, there is the step of removing portions of the layer 36 at essentially the center of the lowest points of the frustrum of the layer 38. Then, there is the step of removing portions of the substrate 34 but not the layer 36 such that a plurality of barbs 16 is created as shown in figure 9d.

The various above embodiments essentially define a connector. The connector is comprised of a first portion which lockingly connects with an object, be it another connector or, for instance, tissue. The connector is also comprised of a base which the first portion is fixedly disposed. The first portion preferably includes a support which extends from the base; and a head which is disposed upon the support and which mates with the object such that a locking connection is formed therebetween, said length of the support and the head being less than 0.5 millimetres.

Preferably, the connector is produced by surface micromachining a full discussion of surface micromachining is found in "Silicon micromechanics: sensors and actuators on a chip' by R. Howe, R. Muller, R. Gabriel and W. Trimmer, IEEE Spectrum, pp. 29-35, July 1990; and "Silicon Micromechanical Devices" by J. Angell, S. Terry and P. Barth, Scientific American, Vol. 248, No. 4, pp. 44-55, April 1983.

In the operation of the preferred embodiment, barbs 16 are formed having dimensions of approximately 4-18 μm wide x 4-18 μm long x 12 μm high. On a given base 22, there are approximately 200,000 individual barbs 16 per cm^2 of base 22. Two essentially identical but opposing plurality of barbs 16 are placed in contact. The application of a minimum compressive force corresponding to about 1.7 psi or 12 kPa to the bases 22 causes the barb 16 to deform and spring back, resulting in an interlocking of the first and second pluralities of barbs 16, (this compares to a value of 7×10^5 kPa (approximately 10^5 psi) which is needed to crush either the first or second plurality of barbs 16.) Thus, the pluralities of barbs 16 self-align and mate. The mated structure has a tensile strength of approximately 1100 Pa, or about 160 psi. In essence, the mating of the first and second pluralities of barbs 16 act as a miniature, single-use, two-dimensional zipper.

Figure 9 describes the process sequence. [100] oriented silicon wafers are thermally oxidized (1000 Å) and patterned into a matrix of 10 μm squares. The SiO_2 squares mask an anisotropic silicon etch in KOH, about 5 μm deep, to form a pattern of frustrums. The wafer is again oxidized, this time to a thickness of 1.0 μm, and patterned with the mask depicted in Figure 10. The patterned oxide acts as a mask for the final step, an isotropic silicon etch to a depth of about 7 μm. An electron micrograph of the completed structure is shown in Figure 6.

The second masking step in this process poses particular difficulties since the surface is highly nonplanar. The wafers are successfully patterned by using a nominal 2.1 μm thick photoresist film, coupled with a relatively long exposure time. The resist thickness, as measured from electron micrographs, is highly nonuniform; it reaches nearly 3.0 μm in the field regions, and is severely thinned over the tops of the frustrums. However, there is adequate thickness to prevent the SiO_2 caps from being attacked in the buffered HF etchant.

The isotropic silicon etch after the second masking step results in considerable lateral undercutting. To prevent this encroachment from weakening the Si support 18 supporting the SiO_2 head 20, two techniques are used: 1) the inside corners of the Greek cross mask pattern are filleted to reduce the undercutting; and 2) the isotropic etch (in $HNO_3/CH_3COOH/HF$) is preceded by an anisotropic etch in ROH. This step reduces the undercutting by supplying most of the needed vertical clearance, without compromising the integrity of the Si support 18.

With respect to the piercing barb 16, this alternative embodiment can be fabricated also with a similar two mask process. The central portion 24 of the head 20 with a piercing barb 16 has a point with a radius of curvature ≥ 0.1 μm.

Although the invention has been described in detail in the foregoing embodiments for the purpose of illustration, it is to be understood that such detail is solely for that purpose and that variations can be made therein by those skilled in the art without departing from the scope of the invention as defined by the following claims.

Claims

1. A micromechanical fastener capable of linking to an object, comprising:

   a base (22);
   a support (18) which extends from, and is in substantially rigid connection with, the base; and
   a head (20) which is disposed upon the support and has a central or connection portion (24) which is in substantially rigid connection with the support, and has an extremity or attachment portion (16, 26) which extends laterally from the central or connection portion and which creates an anchoring connection with the object,
   wherein the combined height of the support and the head above the base is less than 0.5 millimetres;
   wherein the head, base and support are made of a substantially rigid material; and
   wherein the head, base and support form a monolithic structure.

2. A micromechanical fastener according to claim 1, which provides a single-use anchoring connection.

3. A micromechanical fastener according to claim 1 or 2, wherein the central portion (24) is provided with a top surface (32) having a pointed shape that is capable of facilitating penetration of a surface of the object by piercing.

4. A micromechanical fastener according to claim 1,2 or 3, wherein the object is another micromechanical fastener according to claim 1, and the extremity portion (26) is adapted to deflect and subsequently spring back when contacted with an extremity portion of the other micromechanical fastener to form a locking connection therebetween.

5. A micromechanical fastener according to claim 4, wherein the extremity or attachment portion (26) is in the form of a plurality of flanges (30) extending out from the central or connection portion (24), for example so that the head is in the shape of a cross (28) formed of four legs (30).

6. A micromechanical fastener according to claim 4 or 5, wherein the extremity portion (26) which extends from the central portion (24) forms an angle of less

than 90° with the central portion (24) and support (18) such that the extremity portion extends from the central portion toward the base (22).

7. A micromechanical fastener according to any preceding claim, wherein the base (22), head (20) and support (18) are integral with each other.

8. A micromechanical fastener according to any preceding claim, wherein the substantially rigid material is metal, ceramic, plastic, composite material or alloy.

9. A micromechanical fastener according to any preceding claim, wherein the base (22) and support (18) are made of silicon and the head is made of SiO_2.

10. A micromechanical fastener according to any preceding claim, wherein the fastener is produced by surface machining.

11. A micromechanical fastening system, for example for connecting to body tissue (60), comprising a member (50, 66) having at least one surface (54, 56) upon which is disposed a plurality of micromechanical fasteners (16, 58) according to any one of claims 1 to 10, wherein each of the plurality of micromechanical fasteners is adapted to pierce the object and anchor therein.

12. A micromechanical fastening system according to claim 11, wherein the member (50) has a first side (54) and an opposing side (56), the first and opposing sides both having a plurality of micromechanical fasteners (58) thereon.

13. A micromechanical fastener according to claim 11 or 12, wherein the member (52) is annular in shape, and may for example be used where the tissue is a blood vessel (63), the annular fastening system (52) when positioned correctly allowing blood from the blood vessel (63) to flow therethrough.

14. A micromechanical fastening system according to claims 11, 12 or 13 for supplying a drug into an organ (76), which fastening system further comprises a base member (78) with a reservoir to hold the drug, and the plurality of micromechanical fasteners (72) extends from the base member (78) and are able to pierce the organ (76) and maintain the fastening system therein, the fasteners having a channel (82) therethrough which extends to the reservoir such that the drug (74) is placed into fluid communication with the organ.

15. A micromechanical fastening system for linking a first member (12) with a second member (14) comprising:

a first plurality of micromechanical fasteners (16a) according to any one of claims 4 to 10 disposed on the first member;
a second plurality of micromechanical fasteners (16b) according to any one of claims 4 to 10 disposed on the second member;
wherein the first plurality of fasteners and the second plurality of fasteners oppose each other.

16. A micromechanical fastening system according to claim 15, wherein the fasteners of the first plurality of fasteners (16a) and the fasteners of the second plurality of fasteners (16b) are of the same shape.

17. A micromechanical fastening system according to claim 15 or 16, wherein the first member is a first electrical component (86, 92) and the second member is a second electrical component (88, 90, 94) and wherein the first plurality of fasteners (84, 16) are made of an electrically conductive material, and the second plurality of fasteners (84, 16) is made of an electrically conductive material, and the first and second components are in electrical contact through the first and second plurality of fasteners.

18. A method for making a micromechanical fastener according to any one of claims 1 to 10, or a fastening system according to any one of claims 11 to 17, which comprises the steps of:

forming a substrate (34) of a first material from which the base of the fastener is formed;
forming a first layer (36) on the substrate (34) of a second material from which the support is to be formed; and
forming a second layer of a third material at predetermined discrete locations (28) on the layer (36) of second material (Fig. 9a);
removing portions of the first layer (36) and the substrate (34) but not of the second layer (28) such that a frustum shape is formed on the surface of the substrate (Fig. 9b);
removing the second layer but leaving the substrate and first layer essentially untouched (Fig. 9b);
forming a new layer made of the second material on the frustum surface such that the frustum shape is retained (Fig. 9c);
removing portions of the new layer at essentially the centre of the lowest points of the frustum, i.e. from between adjacent frustums (Fig. 9d); and
removing portions of the first layer and the substrate but not the new layer such that the required micromechanical fastener or plurality of

micromechanical fasteners is created (Fig. 9d).

19. A method according to claim 18, wherein the step of removing portions of the new layer includes the step of filleting predetermined areas of the said new layer of the second material to ensure that not too much of the substrate and first layer is removed in the final step of removing portions of the substrate and first layer.

Patentansprüche

1. Mikromechanisches Verbindungselement, das sich an einem Gegenstand verankern lässt und folgende Teile umfasst:

   - eine Grundschicht (22);
   - einen Träger (18), der im wesentlichen starr aus der Grundschicht emporragt; und
   - einen Kopf (20), der auf dem Träger angeordnet ist und einen Zentral- oder Verbindungsteil (24) aufweist, der im wesentlichen starr mit dem Träger verbunden ist und mit seitlichen End- oder Verankerungsteilen (16, 26) versehen ist, die sich seitlich vom Zentral- oder Verbindungsteil erstrecken und eine Verankerung an einem Gegenstand ermöglichen;
   - wobei die gemeinsame Höhe von Träger und Kopf über der Grundschicht weniger als 0.5 mm beträgt,
   - wobei Kopf, Grundschicht und Träger aus im wesentlichen starren Material gefertigt sind und
   - wobei Kopf, Grundschicht und Träger eine monolitische Struktur bilden.

2. Mikromechanisches Verbindungselement nach Patentanspruch 1, welches eine Verankerungsverbindung für den Einmal-Gebrauch bildet.

3. Mikromechanisches Verbindungselement nach Anspruch 1 oder 2, bei dem der Zentralteil (24) oben bei 32 spitzig ausgebildet ist, was das Eindringen in die Oberfläche eines Gegenstandes erleichtert.

4. Mikromechanisches Verbindungselement nach Anspruch 1, 2 oder 3, wobei der zu verbindende Gegenstand ein zweites mikromechanisches Verbindungselement nach Anspruch 1 ist, bei dem der Verankerungsteil (26) sich biegen lässt und danach zurückschnappt, sowie er sich mit anderen mikromechanischen Verbindungselementen zu einer Schliessverbindung vereinigt hat.

5. Mikromechanisches Verbindungselement nach Anspruch 4, wobei der Verankerungsteil (26) mehrere Zacken (30) hat, die sich vom Zentralteil (24) nach aussen erstrecken, beispielsweise in Form eines Kreuzes (28) mit vier Armen (30).

6. Mikromechanisches Verbindungselement nach Anspruch 4 oder 5, wobei der Verankerungsteil (26), der sich vom Zentralteil (24) aus erstreckt, einen Winkel zum Zentralteil und zum Träger (18) von weniger als 90° aufweist, so, dass dessen Enden zur Grundschicht (22) hin gerichtet sind.

7. Mikromechanisches Verbindungselement nach einem der vorhergehenden Ansprüche, wobei die Grundschicht (22), der Kopf (20) und der Träger (18) einstückig miteinander verbunden sind.

8. Mikromechanisches Verbindungselement nach einem der vorhergehenden Ansprüche, wobei das im wesentlich starre (harte) Material aus dem das Verbindungselement hergestellt ist, ein Metall, Keramik, ein Kunststoff, ein Komposit oder eine Legierung ist.

9. Mikromechanisches Verbindungselement nach einem der vorhergehenden Ansprüche, wobei die Grundschicht (22) und der Träger (18) aus Silizium und der Kopf aus SiO_2 hergestellt ist.

10. Mikromechanisches Verbindungselement nach einem der vorhergehenden Ansprüche, wobei das Verbindungselement durch eine Oberflächenbearbeitung hergestellt ist.

11. Verwendung des mikromechanischen Verbindungselementes in einem System, beispielsweise beim Verbinden von Körpergewebeteilen (60) mit Hilfe eines Zwischengliedes (50, 66) mit mindestens einer Oberfläche (54, 56), auf welcher eine Vielzahl von mikromechanischen Verbindungselementen nach einem der Ansprüche 1-10 angebracht ist, die dazu geeignet sind, in den Gegenstand eingestochen zu werden und sich darin zu verankern.

12. Verwendung nach Anspruch 11, wobei das Zwischenglied (50) zwei einander gegenüberliegende Seiten (54, 56) aufweist, welche je mit einer Vielzahl von mikromechanischen Verbindungselementen (58) versehen sind.

13. Verwendung nach Anspruch 11 oder 12, wobei ein ringförmiges Zwischenglied (52) zum Beispiel in das Gewebe eine Blutgefässes (63) eingesetzt wird und bei geeigneter Plazierung das Durchströmen des Blutes ermöglicht.

14. Verwendung nach Anspruch 11, 12 oder 13 bei der Zuführung eines Arzneimittels in ein Körperorgan (76), wobei eine Vielzahl von Verankerungsmittel auf einem Zwischenglied (76) angeordnet ist, wel-

ches einen Arzneimittelbehälter (78) trägt und wobei die mikromechanischen Verbindungselemente (72) im Stande sind, in das Körperorgan (76) einzudringen und sich darin zu verankern, wobei die Verankerungsmittel einen Kanal (82) aufweisen, der sich bis in den Arzneimittelbehälter erstreckt, so dass die Arznei (74) in das Organ gelangt.

15. Verwendung des mikromechanischen Verbindungselementes zur Verbindung einer ersten Grundschicht (12) mit einer zweiten Grundschicht (14), wobei die erste Grundschicht mit einer Vielzahl von mikromechanischen Verbindungselementen (16a) nach einem der Ansprüche 4 bis 10 versehen ist und die zweite Grundschicht mit einer Vielzahl von mikromechanischen Verankerungselementen (16b) nach einem der Ansprüche 4 bis 10 versehen ist, wobei die erstgenannten Verbindungselemente (16a) und die zweitgenannten Verbindungselemente (16b) einander gegenüberliegen.

16. Verwendung nach Anspruch 15, wobei die erstgenannten Verbindungselemente (16a) dieselbe Form haben wie die zweitgenannten Verbindungselemente (16b).

17. Verwendung nach Anspruch 15 oder 16, wobei die erste Grundschicht eine erste elektrische Komponente (86, 92) und die zweite Grundschicht eine zweite elektrische Komponente (88, 90, 94) trägt und wobei die erste Vielzahl von Verbindungselementen (84, 16) aus elektrisch leitendem Material hergestellt ist und die zweite Vielzahl von Verbindungselementen (84, 16) ebenfalls aus elektrisch leitendem Material hergestellt ist, so dass die ersten elektrischen Komponenten und die zweiten elektrischen Komponenten durch die Vielzahl von ersten und zweiten Verbindungselementen miteinander in elektrischen Kontakt gebracht sind.

18. Verfahren zur Herstellung eines mikromechanischen Verbindungselementes nach einem der Ansprüche 1 bis 10 oder für deren Verwendung in einem Verbindungssystem nach einem der Ansprüche 11 bis 17 gemäss den nachfolgenden Schritten:

- Bildung eines Substrats (34) aus einem ersten Material, aus dem die Grundschicht des Verbindungselementes geformt werden soll;
- Anbringen einer ersten Schicht (36) auf dem Substrat (34) eines zweiten Materials, aus welchem der Träger geformt werden soll;
- Anbringen einer zweiten Schicht eines dritten Materials an bestimmten Stellen (28) auf der Schicht (36) aus dem zweiten Material (Figur 9a);
- Entfernen von Teilen der ersten Schicht (36) und des Substrats (34), jedoch nichts von der zweiten Schicht (38), so dass ein Kegelstumpfgebilde auf dem Substrat verbleibt (Figur 9b);
- Entfernen der zweiten Schicht, wobei aber das Substrat und die erste Schicht unangetastet bleiben (Figur 9b);
- Anbringen einer neuen Schicht aus dem zweiten Material auf den Kegelstümpfen, so dass deren Kegelstumpfform erhalten bleibt (Figur 9c);
- Entfernen von Teilen der neuen Schicht, hauptsächlich an den tiefsten Stellen, das heisst zwischen den Kegelstümpfen (Figur 9d); und
- Entfernen von Teilen der ersten Schicht und des Substrats, aber nicht von der neuen Schicht, wodurch eine Vielzahl der gewunschten mikromechanischen Verbindungselemente gebildet wird (Figur 9d).

19. Verfahren nach Anspruch 18, wobei während der durchführung des Schrittes, bei welchem bestimmte Teile der neuen Schicht entfernt werden, durch Filetieren dafür gesorgt wird, dass bei der Durchführung des letzten Schrittes nicht zuviel Substrat und nicht zuviel der ersten Schicht entfernt wird.

Revendications

1. Attache micromécanique capable d'une liaison avec un objet, comprenant:

   une base (22);
   un support (18) qui s'étend depuis la base et est relié de façon sensiblement rigide à cette base; et
   une tête (20) qui est disposée sur le support et comporte une partie centrale ou de liaison (24) qui est reliée de façon sensiblement rigide au support, et comporte une partie d'extrémité ou de fixation (16, 26) qui s'étend latéralement depuis la partie centrale ou de liaison et qui crée une liaison d'ancrage avec l'objet,
   dans lequel la hauteur combinée du support et de la tête au-dessus de la base est inférieure à 0,5 millimètres;
   dans lequel la tête, la base et le support sont constitués d'un matériau sensiblement rigide; et
   dans lequel la tête, la base et le support forment une structure monolithique.

2. Attache micromécanique selon la revendication 1, qui assure une liaison d'ancrage non-réutilisable.

3. Attache micromécanique selon la revendication 1 ou 2, dans lequel la partie centrale (24) est pourvue d'une surface supérieure (32) ayant une forme poin-

tue qui est capable de faciliter la pénétration d'une surface de l'objet par percement.

4. Attache micromécanique selon la revendication 1, 2 ou 3, dans lequel l'objet est une autre attache micromécanique selon la revendication 1, et la partie d'extrémité (26) est adaptée pour fléchir et ensuite reprendre élastiquement sa forme initiale quand elle mise en contact avec une partie d'extrémité de l'autre attache micromécanique, de manière à former une liaison verrouillée entre ces deux attaches.

5. Attache micromécanique selon la revendication 4, dans lequel la partie d'extrémité ou de fixation (26) se présente sous la forme d'une pluralité d'ailes (30) s'étendant vers l'extérieur depuis la partie centrale ou de liaison (24) par exemple de manière que la tête ait la forme d'une croix (28) formée de quatre branches (30).

6. Attache micromécanique selon la revendication 4 ou 5, dans lequel la partie d'extrémité (26) qui s'étend depuis la partie centrale (24) fait un angle de moins de 90° avec la partie centrale (24) et le support (18), de sorte que la partie d'extrémité s'étend depuis la partie centrale en direction de la base (22).

7. Attache micromécanique selon l'une quelconque des revendications précédentes, dans lequel la base (22), la tête (20) et le support (18) font corps les uns avec les autres.

8. Attache micromécanique selon l'une quelconque des revendications précédentes, dans lequel le matériau sensiblement rigide est un métal, une céramique, une matière plastique, un matériau composite ou un alliage.

9. Attache micromécanique selon l'une quelconque des revendications précédentes, dans lequel la base (22) et le support (18) sont en silicium et la tête est en SiO_2.

10. Attache micromécanique selon l'une quelconque des revendications précédentes, dans lequel l'attache est produite par usinage de surface.

11. Système d'attache micromécanique, par exemple pour être fixé à un tissu corporel (60), comprenant un élément (50, 66) comportant au moins une surface (54, 56) sur laquelle est disposée une pluralité d'attaches micromécaniques (16, 58) selon l'une quelconque des revendications 1 à 10, dans lequel chacune des attaches de la pluralité d'attaches micromécaniques est adaptée pour percer l'objet et s'y ancrer.

12. Système d'attache micromécanique selon la revendication 11, dans lequel l'élément (50) comporte un premier côté (54) et un côté opposé (56), le premier côté et le côté opposé portant tous deux une pluralité d'attaches micromécaniques (58).

13. Attache micromécanique selon la revendication 11 ou 12, dans lequel l'élément (52) a une forme annulaire, et peut par exemple être utilisé lorsque le tissu est un vaisseau sanguin (63), le système d'attache annulaire (52), quand il est positionné correctement, permettant au sang provenant du vaisseau sanguin (63) de s'écouler à travers ce dernier.

14. Système d'attache micromécanique selon les revendications 11, 12 ou 13 pour introduire un médicament dans un organe (76), ce système d'attache comprenant, en outre, un élément de base (78) muni d'un réservoir pour contenir le médicament, et la pluralité d'attaches micromécaniques (72) s'étendent depuis l'élément de base (78) et sont capables de percer l'organe (76) et d'y maintenir le système d'attache, les attaches comportant un canal traversant (82) qui s'étend jusqu'au réservoir de telle sorte que le médicament (74) se trouve en communication d'écoulement de fluide avec l'organe.

15. Système d'attaches micromécaniques servant à relier une premier élément (12) à un deuxième élément (14), comprenant:

    une première pluralité d'attaches micromécaniques (16a) selon l'une quelconque des revendications 4 à 10, disposées sur le premier élément ;
    une deuxième pluralité d'attaches micromécaniques (16b) selon l'une quelconque des revendications 4 à 10, disposées sur le deuxième élément ;
    dans lequel la première pluralité d'attaches et la deuxième pluralité d'attaches sont en opposition mutuelle.

16. Système d'attache micromécanique selon la revendication 15, dans lequel les attaches de la première pluralité d'attaches (16a) et les attaches de la deuxième pluralité d'attaches (16b) ont la même forme.

17. Système d'attache micromécanique selon la revendication 15 ou 16, dans lequel le premier élément est un premier composant électrique (86, 92) et le deuxième élément est un deuxième composant électrique (88, 90, 94) et dans lequel la première pluralité d'attaches (84, 16) est formée d'un matériau conducteur de l'électricité, et les premier et deuxième composants sont en contact électrique par l'intermédiaire des première et deuxième plura-

lités d'attaches.

18. Procédé pour fabriquer une attache micromécanique selon l'une quelconque des revendications 1 à 10, ou système d'attache selon l'une quelconque des revendications 11 à 17, qui comprend les étapes consistant à

    former un substrat (34) en un premier matériau dont est formée la base de l'attache;
    former sur le substrat (34) une première couche (36) en un deuxième matériau dont le support doit être formé; et
    former une deuxième couche d'un troisième matériau à des endroits discrets prédéterminés (28) sur la couche (36) du deuxième matériau (Fig. 9a);
    enlever des parties de la première couche (36) et du substrat (34) mais pas de la deuxième couche (28) de telle sorte qu'une forme tronconique soit créée sur la surface du substrat (Fig 9b);
    enlever la deuxième couche mais en laissant essentiellement intacts le substrat et la première couche (fig. 9b);
    former une nouvelle couche du deuxième matériau sur la surface tronconique de telle manière que la forme tronconique soit maintenue (Fig. 9c);
    enlever des parties de la nouvelle couche essentiellement au centre des points les plus bas du tronc de cône, par exemple entre des troncs de cônes adjacents (fig. 9d); et
    enlever des parties de la première couche et du substrat mais non pas la nouvelle couche de telle sorte que l'attache micromécanique requise ou la pluralité d'attaches micromécaniques requise soit créée (fig. 9d).

19. Procédé selon la revendication 18, dans lequel l'étape consistant à enlever des parties de la nouvelle couche comprend l'étape consistant à profiler des zones prédéterminées de ladite nouvelle couche de deuxième matériau pour qu'à coup sûr ne soit pas enlevée une trop grande quantité du substrat et de la première couche au cours de l'étape finale d'enlèvement des parties du substrat et de la première couche.

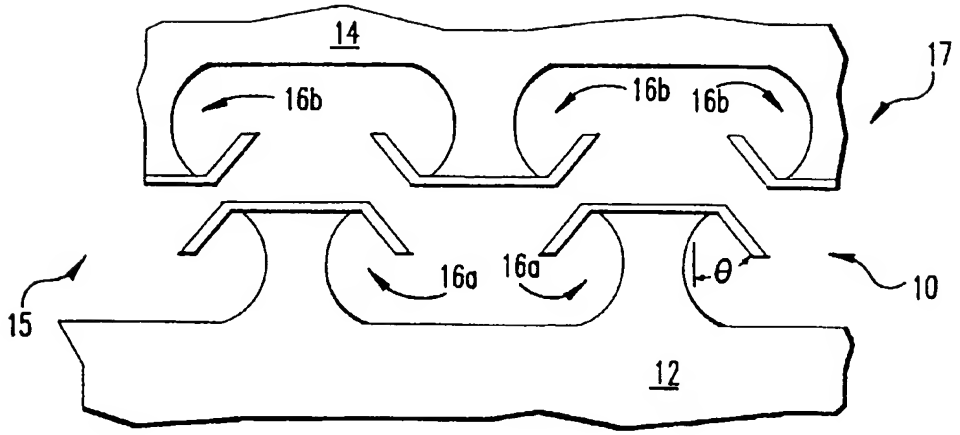


FIG.1

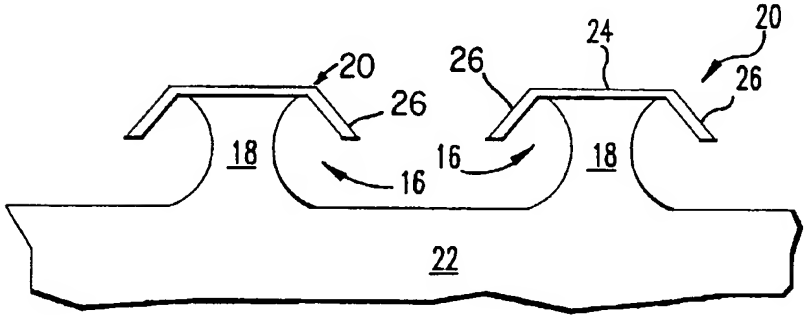


FIG.2

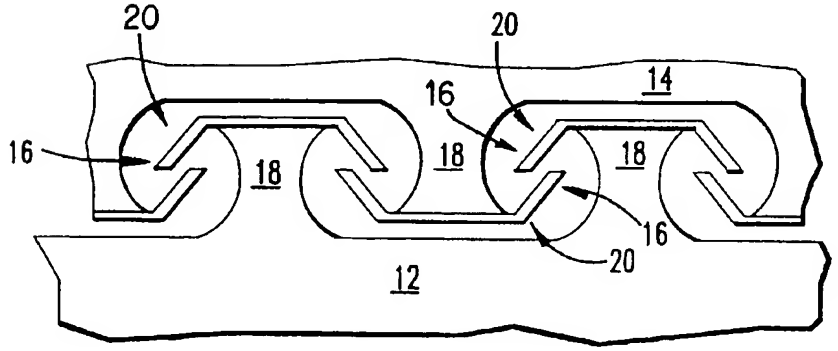


FIG.3

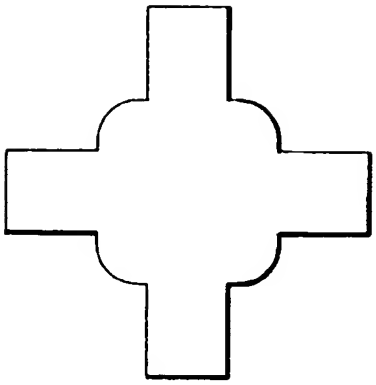


FIG.4

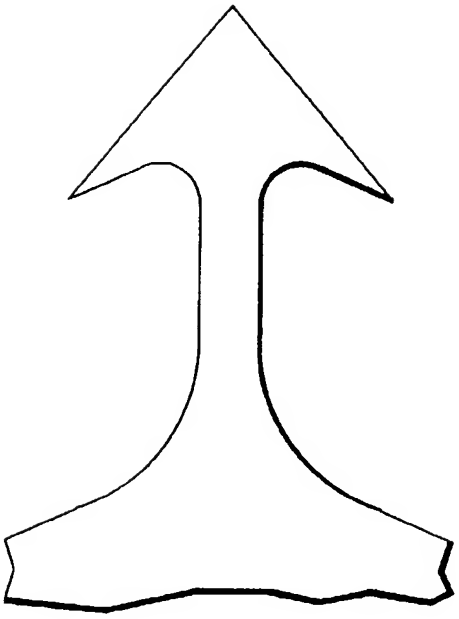
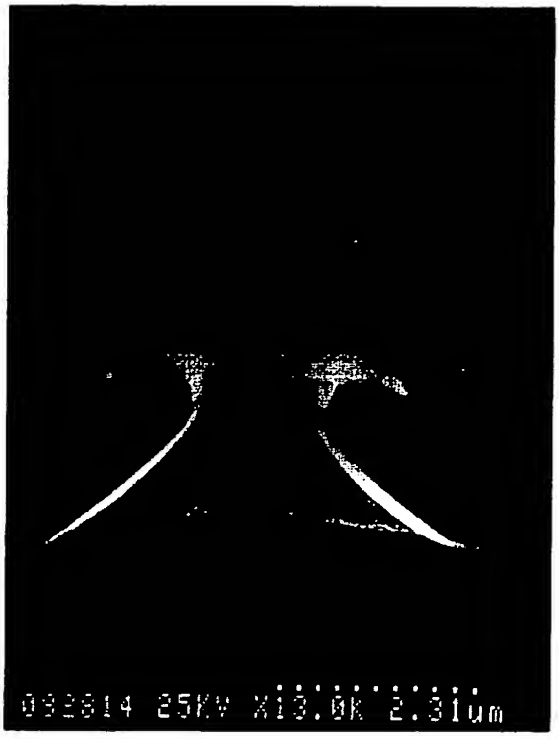


FIG.6

FIG. 5

FIG. 7



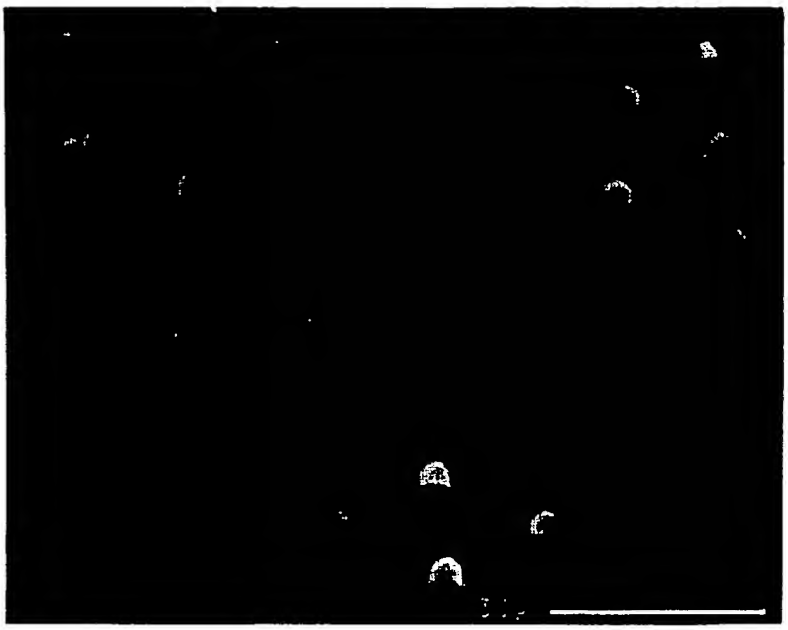


FIG. 8

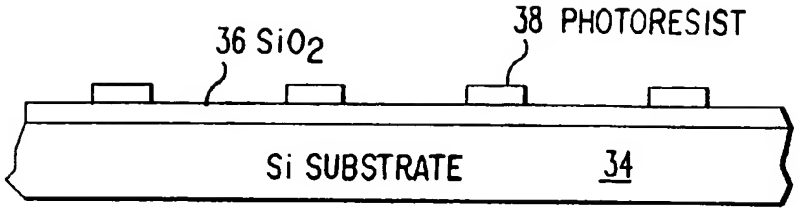


FIG.9a

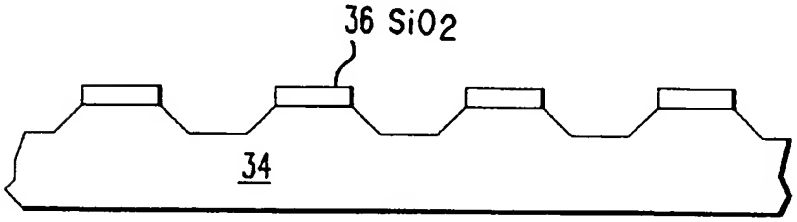


FIG.9b

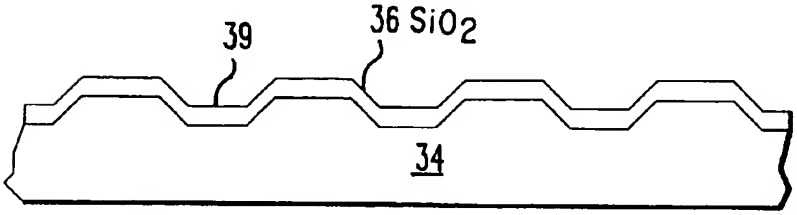


FIG.9c

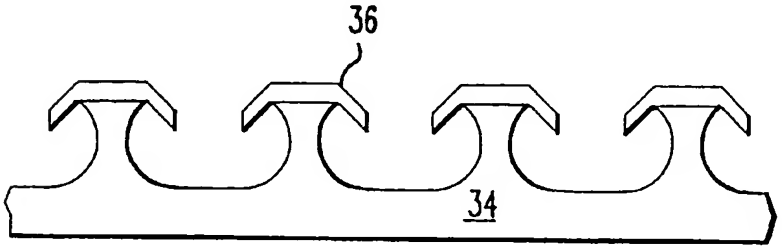


FIG.9d

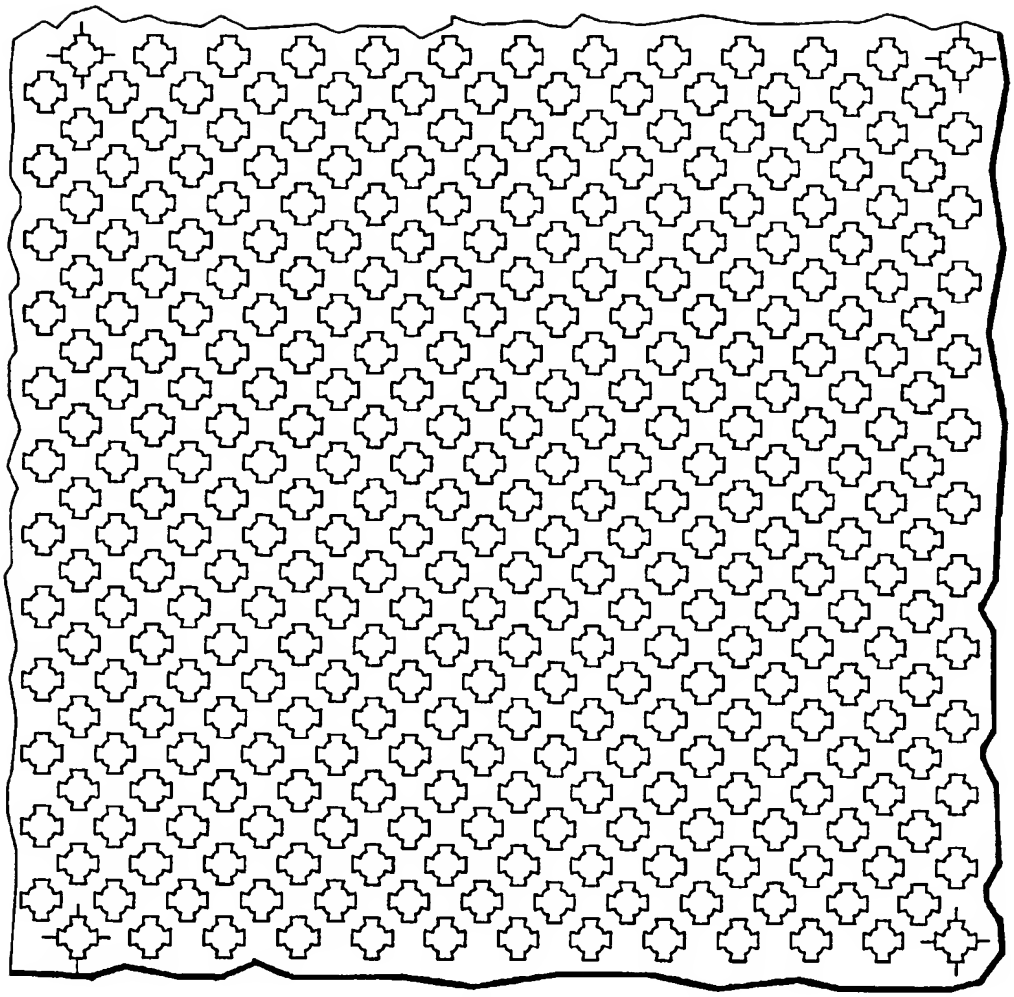


FIG.10

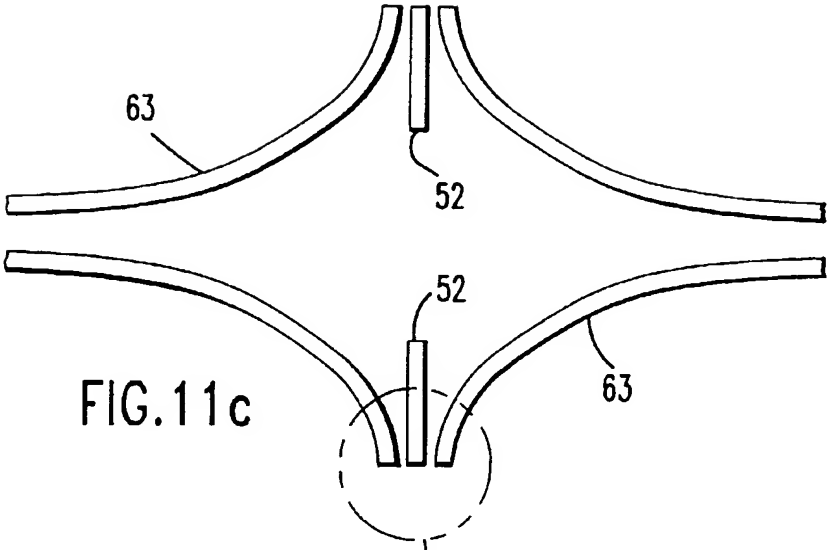


FIG.11c

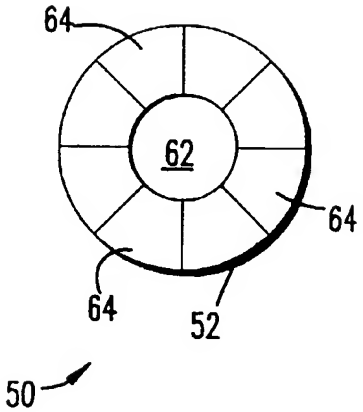


FIG.11a

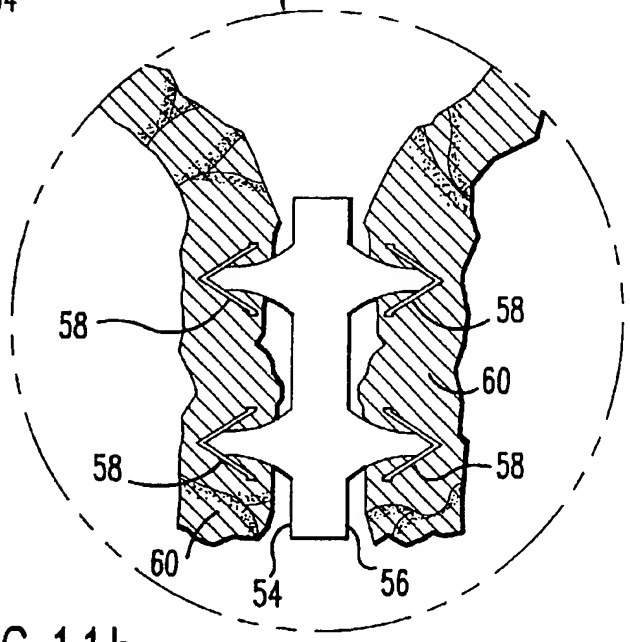


FIG.11b

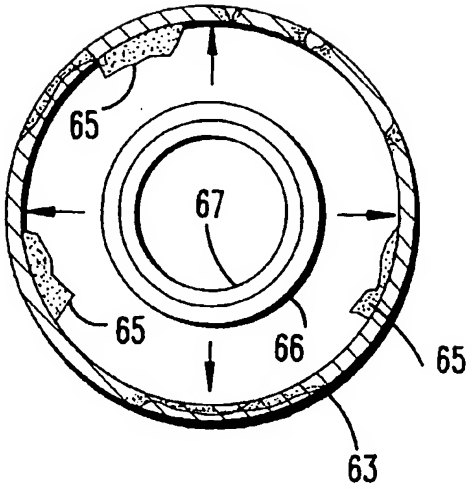


FIG.12a

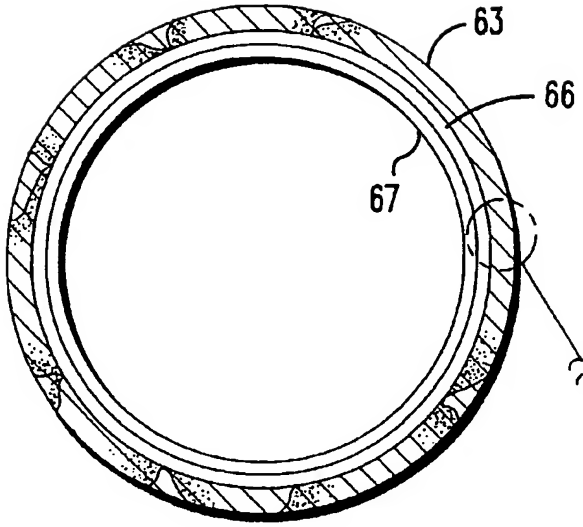


FIG.12b

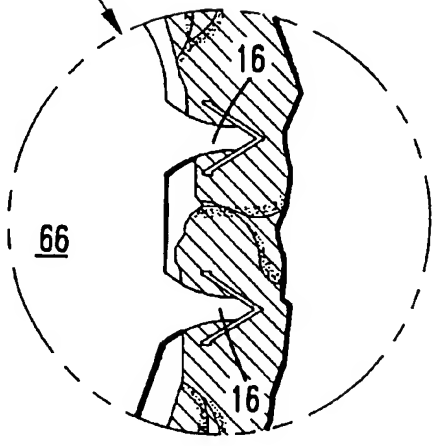
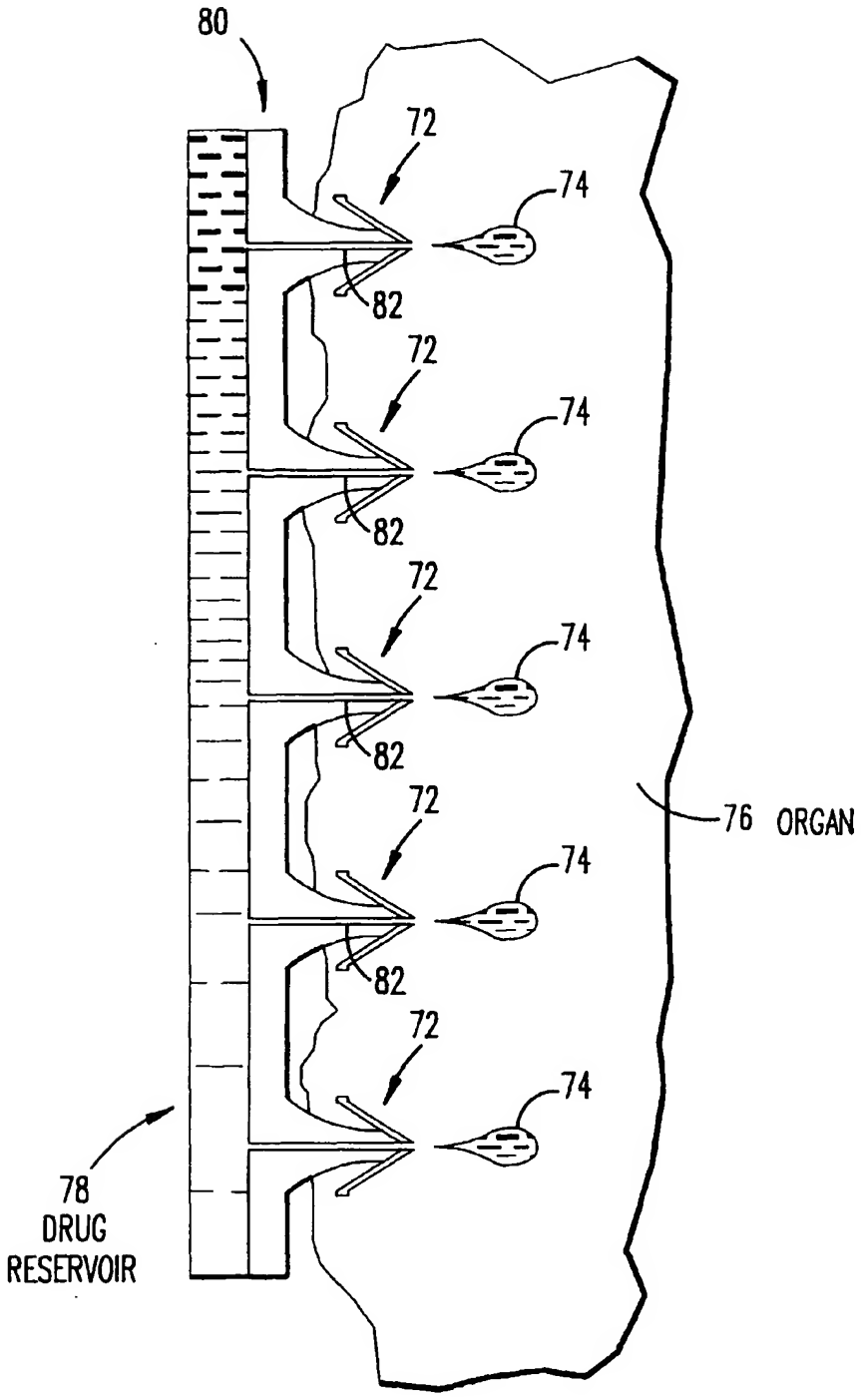


FIG.12c


80
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76 ORGAN
78
DRUG
RESERVOIR

FIG.13

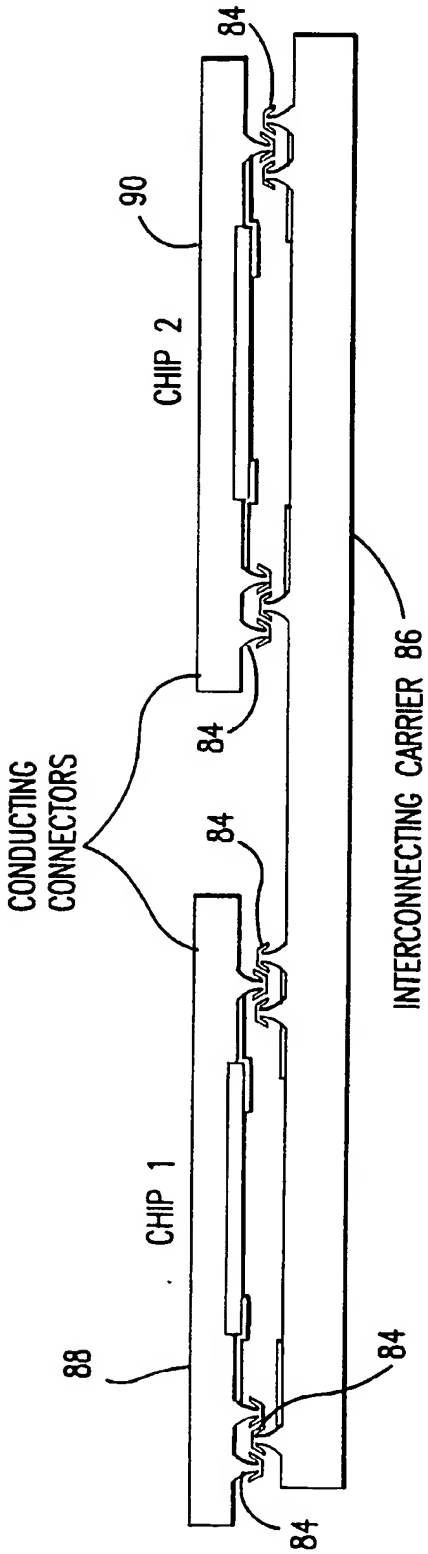
84
90
CHIP 2
84
CONDUCTING CONNECTORS
84
INTERCONNECTING CARRIER 86
CHIP 1
88
84
84

FIG.14

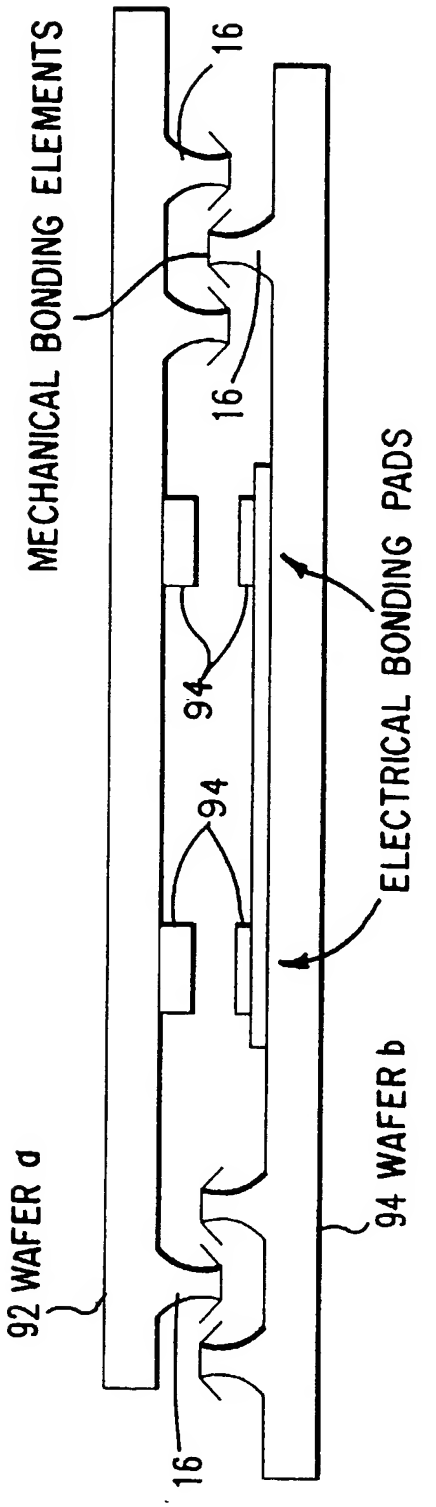
MECHANICAL BONDING ELEMENTS
16
16
94
94
ELECTRICAL BONDING PADS
92 WAFER a
94 WAFER b
16

FIG.15